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"OBSERVATIONAL RESULTS OF MICROWAVE TEMPERATURE PROFILE MEASUREMENTS FROM THE AIRBORNE ANTARCTIC OZONE EXPERIMENT"

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INTRODUCTION

The Microwave Temperature Profiler, MTP, is installed on NASA's ER-2 aircraft. MTP measures profiles of air temperature versus altitude. Temperatures are obtained every 13.7 seconds for 15 altitudes in an altitude region that is approximately 5 km thick (at high flight levels). MTP is a passive microwave radiometer, operating at the frequencies 57.3 and 58.8 GHz. Thermal emission from oxygen molecules provides the signal that is converted to air temperature. MTP is unique, in that it is the only airborne instrument of its kind.

The MTP instrument was used during the Airborne Antarctic Ozone Experiment, AAOE, to enable "potential vorticity" to be measured along the flight track. Other uses for the MTP data have become apparent. The most intriguing unexpected use is the detection and characterization of mountain waves that were encountered during flights over the Palmer Peninsula. These and other observations will be described.

ALTITUDE TEMPERATURE PROFILES

The MTP's basic observational product is air temperature at 15 altitudes every 13.7 seconds, as illustrated below:

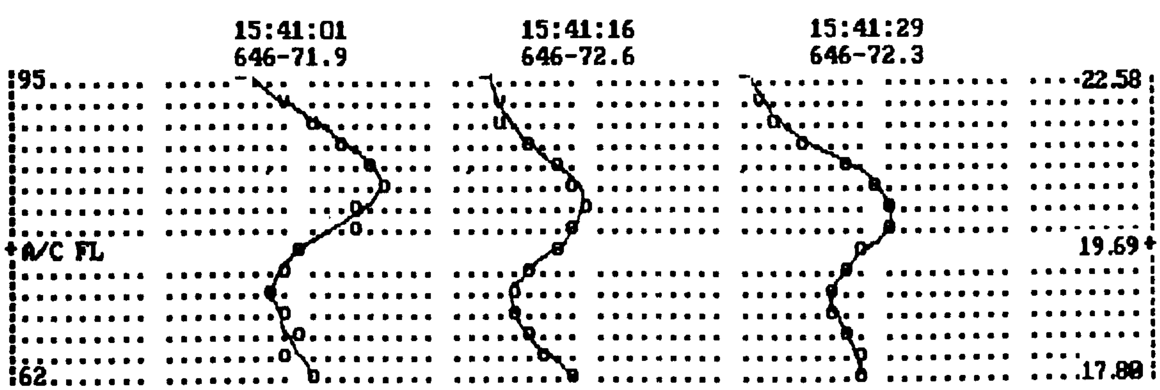

Figure 1. A sequence of 3 altitude temperature profiles.

The above profiles were taken during level flight at 64,600 feet (pressure altitude). The temperature scale is 0.25 K/column. The altitude scale extends from 6200 feet below to 9500 feet above flight level. Pressure altitudes, in km, are shown on the right. Below the time blocks are flight level (in units of 100 feet) and outside air temperature [degC]. This figure shows that the aircraft is flying within an inversion layer that is 5000 feet thick and is about 1.4 degC warmer at the top than at the bottom. Slow changes in inversion layer properties are evident.

LAPSE RATE AND POTENTIAL VORTICITY

From the altitude temperature profiles it is possible to calculate lapse rate, dT/dz, by comparing temperatures at altitudes above and below flight level. This parameter can be converted to potential temperature lapse rate, d(theta)/d(pressure), using standard equations. Potential temperature is defined as: theta = T*(1000mb/pressure)^.286, where T is air temperature [K]. Potential vorticity is the product of potential temperature lapse rate and horizontal wind gradient (to first order). The ER-2's Meteorology Measurement System, MMS, measures wind vector versus time. Combining observations of MTP and MMS thus enables potential vorticity to be calculated. Potential vorticity is a conservative property of air parcels on suitably short timescales; hence, it can be used as a constraint on scenarios for the recent history of air parcels.

An inspection of potential temperature lapse rate versus latitude, for flights which penetrated into the volume of air with high chlorine monoxide and low ozone, failed to show a noticeable change at the boundary. An analysis described elsewhere (Hartmann et al, 1988), which uses the MMS and MTP combined data sets for a calculation of potential vorticity versus latitude, does show a correlation with penetration into the ozone hole.

POTENTIAL TEMPERATURE CROSS-SECTIONS

Each altitude temperature profile can be converted to a profile of potential temperature. Interpolations can be made for deriving altitudes of potential temperature surfaces. A time series of such potential temperature surface altitudes can be used to create "potential temperature cross-sections."

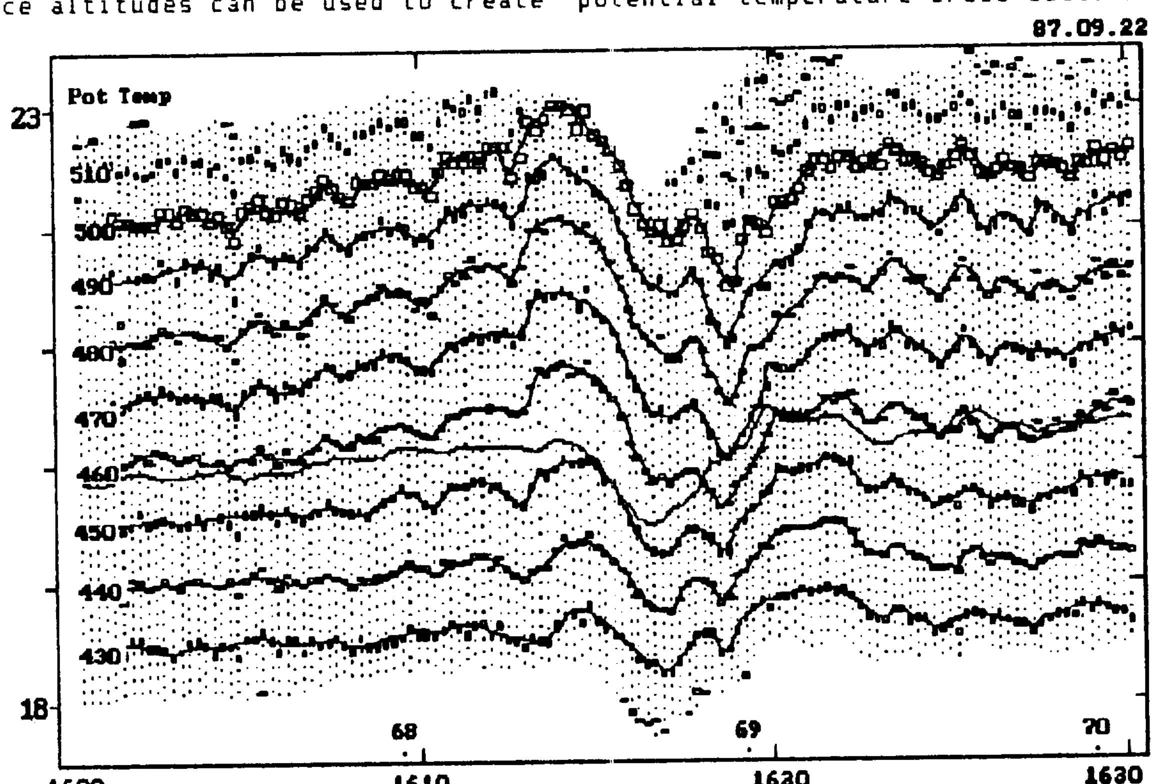

Figure 2. Potential temperature cross-section for a mountain wave encounter, 1987 September 22. Altitude [km] is indicated on the left, UT times below.

In the above figure the pressure altitudes for selected potential temperatures are plotted with coded symbols. The 500 K altitudes are plotted with large squares. Hand-fitted lines are shown for potential temperature surfaces at 10 K intervals. The extra trace, at about 20 km (or 457 K), is the ER-2's flight level. Note the flight level excursions, at 1615 to 1620 UT, caused by down- and up-drafts.

MOUNTAIN WAVE ENCOUNTERS

Potential temperature cross-sections show "waves" of some amplitude and period almost all the time. Generally, wave amplitudes are less than 200 meters, peak-to-peak, and their wavelengths are longer than 100 km. On 12 occasions waves were encountered that differed in 3 ways: they had higher amplitudes (200 to 1200 meters), much shorter wavelengths (typically 20 km), and they existed at all altitudes sampled (18 to 23 km, typically).

An analysis of the location of the aircraft when these high amplitude, short period waves were encountered shows that they always occurred over the Palmer Peninsula. An analysis was made of the likelihood of encountering these waves for each of the regions where several overflights occurred. The waves were encountered at the south end of Palmer Peninsula 64% of the time. The northern half of the peninsula had an encounter probability of 30%. Flights were not made near the eastern edge of the peninsula because the pilots noted wave clouds in those regions.

On 3 consecutive flights, September 20, 21 and 22, a short period wave group was encountered at approximately the same location on both the outbound and inbound legs of the flight. Presumably this was the "same" wave that persisted for at least 3 days. It may have lasted longer, since the 22nd was the last flight over the Palmer Peninsula.

It is reasonable to conclude, based on the strong correlation of high amplitude waves of short period with underlying topography, that the entire Palmer peninsula was producing mountain waves; and that the mountain wave production rate was ranged from at least 30% at the north end to at least 64% at the south end.

It is noteworthy that these waves extended from the lowest altitudes sampled by the MTP instrument to the highest. Figure 2 shows the highest amplitude wave encountered, and it's amplitude is 1.2 km at the highest altitudes. Mountain wave theory predicts that wave amplitude should increase with altitude in accordance with the reciprocal of the square root of air pressure. On average, the waves encountered over Palmer Peninsula obey this relationship.

IMPLICATIONS FOR OZONE HOLE

Mountain waves that propagate into the polar vortex may have implications for the formation of the ozone hole. Upward excursions of air parcels lead to a brief cooling. This can begin the process of cloud formation. It is important to determine how much additional formation of polar stratospheric cloud (PSC) material is possible by the passage of air parcels through a mountain wave pattern that endures for long periods. Other mountain wave effects have been suggested, such as a speeding up of the vortex, and a consequent cooling of large air volumes (which in turn might add to PSC production).